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ORIGINAL RESEARCH

THE RELATIONSHIP BETWEEN TRUNK ROTATION, UPPER QUARTER DYNAMIC STABILITY, AND THE KERLAN-JOBE ORTHOPAEDIC CLINIC OVERHEAD ATHLETE SHOULDER AND ELBOW SCORE IN DIVISION I COLLEGIATE PITCHERS

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ABSTRACT

Hypothesis/Purpose: The purpose of this study was to assess relationships between active trunk rotation range of motion (TROM), upper quarter dynamic stability, and composite and individual item KJOC scores in collegiate baseball pitchers. A secondary purpose was to determine whether differences exist between baseball pitchers with and without an injury history in terms of their performance on TROM, upper quarter dynamic stability, and composite and individual KJOC scores. It was hypothesized that increased TROM and upper quarter dynamic stability are associated with better (higher) KJOC scores and pitchers with an injury history would exhibit lower KJOC scores compared to uninjured pitchers.

Study Design: Cross-sectional Cohort Study

Methods: Thirty-six college pitchers were assessed for TROM, performance on the Upper Quarter Y-Balance Test (YBT-UQ) and they also completed the KJOC. Subjects were grouped based on previous injury history: injured, required surgery, (IS, n = 9), injured, no surgery, (INS, n = 6), and uninjured (UI, n = 21). Pearson's Correlations were used to assess relationships between clinical measurements and the KJOC. One-way ANOVAs were used to assess differences in TROM, YBT-UQ, and KJOC scores between groups ($P < 0.05$).

Results: No significant relationships were detected between TROM measures and KJOC composite scores (throwing arm: $r = .239$, $p = 0.16$; non-throwing arm: $r = .291$, $p = 0.09$). A moderate relationship was found between the YBT-UQ and the KJOC scores (throwing arm: $r = .413$, $p = 0.01$; non-throwing arm: $r = .380$, $p = 0.02$). The mean KJOC scores for item 1 (warm-up limitations) were significantly different between all three groups (IS: 6.7, INS: 9.7, UI: 9.1; $p = 0.015$). Mean scores on item 5 (strain on relationships with coaches) and item 8 (limitations in competition endurance) were significantly different between the IS and UI groups (Item 5 = IS: 7.8, UI: 9.5, $p = 0.02$; Item 8 = IS: 6.4, UI: 8.8, $p = 0.04$).

Conclusion: A positive moderate association was found between upper quarter dynamic stability as measured by the YBT-UQ and the KJOC. Pitchers with no surgical history had better KJOC scores for warm up time, competitive endurance, and impact on team relationships.

Level of Evidence: 3

Key Terms: Baseball, Throwing, Trunk Mobility, Y-Balance Test

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INTRODUCTION

Baseball is one of the most popular sports around the world and, as "America's Pastime", has over 13 million annual participants in the United States alone.[1] Of those, nearly half a million high school students participate in baseball and more than 34,000 will go on to play at the collegiate level.[2] Increasing concern has been raised regarding upper extremity injury, especially in pitchers.[3,4] Posner et al.[4] indicated that over a seven-year period in Major League Baseball, pitchers had a 34% increased injury incidence compared to fielders and that 62% of all disability days were due to injury in pitchers. Similar results were also found by Conte et al.,[5] who concluded that 56.9% of the total disabled-list days were accrued by pitchers. Dick et al.[6] found that in a 16-year period, 59.5% of college baseball injuries involved throwing, with pitching accounting for 73% of those injuries. Despite the high prevalence,[4-6] clinicians continue to lack clear understanding of all the contributing factors.

To better care for baseball players, clinicians often screen and examine various movements in order to identify impairments that may contribute to injury.[7] One common measurement researchers have investigated is active trunk rotation range of motion.[8-11] During pitching there is a force exchange that takes place about the trunk, initiating in the lower extremity and progressing to the upper extremity.[11] Adequate rotational motion is needed in the trunk during pitching to make this transfer of kinetic energy possible.[8-10] In fact, Stodden et al.[9] determined that increased upper trunk rotational momentum correlated to greater pitching velocity.

In addition to trunk rotational motion during pitching,[9] trunk stability during dynamic motion may also play a role.[12,13] Dynamic stability is the capability of an athlete to stabilize the body's center of mass during distal extremity excursion.[14] One test that incorporates upper quarter dynamic stability is the Upper Quarter Y-Balance Test (YBT-UQ) due to its combination of core and scapular stability demands as the subject reaches as far as possible with one upper extremity while weight bearing on the other, without loss of balance.[13] The YBT-UQ integrates three reach directions: medial (M), inferolateral (IL) and superolateral (SL), in a unilateral three-point plank position.[13] The YBT-UQ has been determined to be reliable for test-retest and inter-rater reliability.[12,13,15] While pitching is considered an open chain movement of the upper extremity, previous authors[7,16,17] have illustrated the importance of closed chain testing to fully examine upper quarter function. Butler et al.[7] revealed no upper quarter dynamic stability differences between throwing and non-throwing upper extremities in uninjured high school baseball and softball players. Garrigues et al.[17] observed that high school and collegiate baseball players performed equally on the YBT-UQ. Thus, closed chain testing appears to be suitable to effectively assess upper quarter dynamic stability.[7,17]

Along with examining trunk rotation and upper quarter dynamic stability, sports medicine clinicians often use patient reported outcome measures to assess their athlete's attitudes or subjective perceptions. The Kerlan-Jobe Orthopaedic Clinic Overhead Athlete Shoulder and Elbow Score (KJOC) is a 10-item questionnaire focused on the upper extremity in overhead athletes.[18-23] The KJOC has been validated and shown to have reliability as a functional assessment tool in the overhead athlete.[19] The KJOC has also demonstrated greater responsiveness than other outcome forms with regards to overhead athletes.[18,19,22] Alberta et al.[19] compared the KJOC to the Disabilities of the Arm Shoulder and Hand (DASH) and the DASH sports/performing arts module, finding the KJOC to be more responsive to changes in the overhead athlete. In addition to establishing reliability, they found that the KJOC scores correlated with athlete playing status on injury and injury history. As the injured athletes improved over time, so did their KJOC scores. Domb et al.[18] compared the KJOC to both DASH versions and identified the KJOC as the most sensitive outcome measure for detecting subtle changes in throwing athlete performance. Neri et al.[22] found the KJOC to be more accurate than American Shoulder and Elbow Surgeon's score (ASES) in evaluating overhead athletes with superior labrum anterior to posterior (i.e., SLAP) repairs. In addition to comparing it with other outcome forms, researchers have attempted to establish normative data for the KJOC in baseball players,[20,21] and one author has suggested KJOC scores can be used to predict in-season injuries.[23]

Despite being well studied in baseball players,[18,20,21,23] there is a paucity of literature investigating the KJOC's relationship to clinical measures. This study will give clinical insight into whether or not healthy collegiate pitching populations need further clinical assessment, elucidated through an overhead athlete specific patient reported outcome measure. Further, this study will aid clinicians by offering a better understanding of how upper quarter dynamic stability and trunk rotation relate to patient reported outcomes, which then can be utilized as clinical benchmarks in overhead athlete return to sport criteria. Therefore, the purpose of this study was to assess relationships between active trunk rotation range of motion (TROM), upper quarter dynamic stability, and composite and individual item KJOC scores in collegiate baseball pitchers. A secondary purpose was to determine whether differences exist between baseball pitchers with and without an injury history in terms of their performance on TROM, upper quarter dynamic stability, and composite and individual KJOC scores. It is hypothesized that (1) greater trunk rotation and increased performance with upper quarter dynamic stability are associated with higher composite scores on the KJOC and (2) pitchers with an injury history will exhibit decreased trunk rotation, decreased upper quarter dynamic stability performance, and lower KJOC scores compared to their uninjured counterparts.

METHODS

Participants

A cohort of thirty-six college baseball pitchers were recruited for this study from three Division I universities. Data were collected prior to routine practices at the pitcher's respective home practice fields during the pre-season. To avoid bias, subjects were included only if they were fully participating in all practices, training sessions, and pre-season games. Exclusion criteria consisted of a reporting of any current injury or pain while performing the active trunk ROM, the YBT-UQ, or during any baseball activity. Prior to participation, all subjects were informed of the risks and benefits and gave signed consent. Duke University's Institutional Review Board approved this study. The subjects' descriptive statistics are presented in Table 1.

Table 1. *Variables of interest before and after the low-intensity stiff-leg deadlift in normal and decreased hamstring flexibility groups.*

	Injured, surgical (IS), n=9	Injured, no surgery (INS), n=6	Uninjured (UI), n=21
Height (m)	1.87 ± 0.04	1.87 ± 0.04	1.88 ± 0.06
Mass (kg)	91.8 ± 8.1	88.4 ± 8.4	89.1 ± 8.3
Age (yrs)	21.1 ± 1.7	20.0 ± 0.9	20.2 ± 1.3

Procedures

Kerlan-Jobe Orthopaedic Clinic Overhead Athlete Shoulder and Elbow Score

The KJOC score is comprised of demographic information and a 10-item questionnaire.[18] Prior to all other data collection, the KJOC was administered to each subject. As part of the demographic information gathered for the KJOC score, players were asked about their injury and treatment history. This information, not included in the players KJOC score, was used exclusively to classify pitchers into injury groups. The 10-item questionnaire is a patient reported outcome for upper extremity functional performance in the overhead athlete. All 10 questions use a visual analog scale where the player marks an X along a 10-cm line, with the far right indicating higher function (10) and the far left indicating lower function (0). The mark was measured by a single rater to the nearest millimeter to obtain a numerical value for each question. The 10 questions were averaged to compute a composite score out of 100, with higher scores indicating higher function.

Based on the subjects' responses to the historic injury and treatment questions, the following three groups were identified: pitchers with a previous injury requiring surgery (injured, surgical; IS, n = 9), pitchers with a previous injury not requiring surgery (injured, no surgery; INS, n = 6), and those with no injury history (uninjured; UI, n = 21). All reported injuries were to either the shoulder girdle, shoulder, elbow, or forearm.

Trunk rotation

Active trunk rotation was assessed using a protocol studied by Johnson et al.[24] who found it to be reliable when performed by more than one tester, within healthy active adult populations. This method utilized a standardized backless seat, with

hips and knees flexed to 90 degrees. To facilitate proper hip and knee alignment, the feet were elevated with dense foam pads of varying widths. A test administrator placed a ball (21 cm diameter) between the knees of each athlete and instructed subjects to lightly squeeze the ball. A 48" long dowel rod was placed anterior to the participant, across the middle of the manubrium, with the arms crossed in front of the dowel (Figure 1)**.** The test administrator employed a calibrated electronic goniometer (PT Goniometer, Version 1.1, Copyright © Mark Busman, 2015), positioned parallel to the ground and located between the T1 and T2 spinous process, with C7 and the spine of the scapula utilized for orientation. Subjects were directed to maintain gaze direction at a point at eye level, while rotating to their maximum end range to one side. At rotation end range, the test administrator recorded the measurement. The averages of two trials of right and left trunk rotation were used for analysis.[24]

Upper Quarter Y-Balance Test

The YBT-UQ, using a Y-Balance testing kit (Functional Movement Systems Inc., Chatham, VA, USA), was evaluated prior to warm up and pitching. Test administrators were all trained and certified in the YBT-UQ procedure (Functional Movement Systems Inc., Chatham, VA, USA). Upper extremity limb length was measured with a cloth tape from the seventh cervical vertebral spinous process to the tip of the longest finger on the right arm. Subjects were positioned standing with feet together, upper limbs abducted to 90 degrees, elbows extended and wrists in anatomic position. Subjects' upper extremity limb length was measured twice for accuracy.

Before upper quarter dynamic stability testing, a test administrator educated each subject on the YBT-UQ protocol.[13] Athletes were positioned in a three-point plank position with feet shoulder width apart. The support hand was placed on the centralized platform with the hand in the proper position according to the test guidelines. Subjects were instructed to adhere to the following standards during each test trial 1) three points of contact, consisting of the patient's two feet and support hand, were to be preserved throughout each trial, 2) to advance the reach indicator, momentum (i.e., a push) was not to be used, 3) only the designated area on the reach indictor was to be applied for progression, 4) increased stability was not to be extended by pushing on the top of the indicator, reach pole or the ground, 5) when returning back to the starting position, balance must be maintained by the reaching arm not touching the ground before coming back to the starting position. Athletes were instructed that if these criteria were not fulfilled, the test would be considered erroneous, and they would have to repeat the trial. In a three-point plank position, each pitcher pushed the reach indicator with most distal aspect of the opposite hand in the M, IL and SL positions (all reach directions are with respect to the stance limb) (Figure 2). All

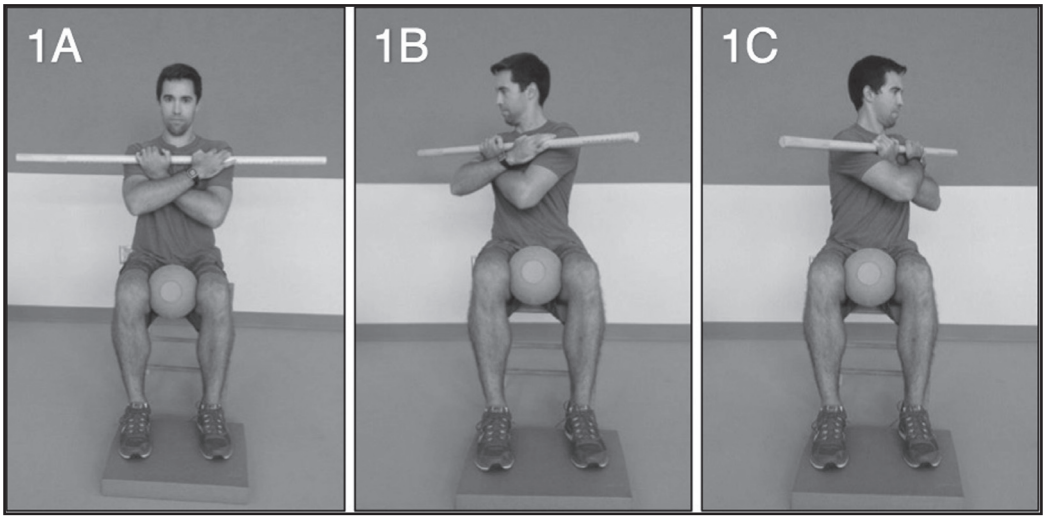

Figure 1. *Active Trunk Rotation Measurement Technique; (1A) Starting Position, (1B) Rotation Right, (1C) Rotation Left.*

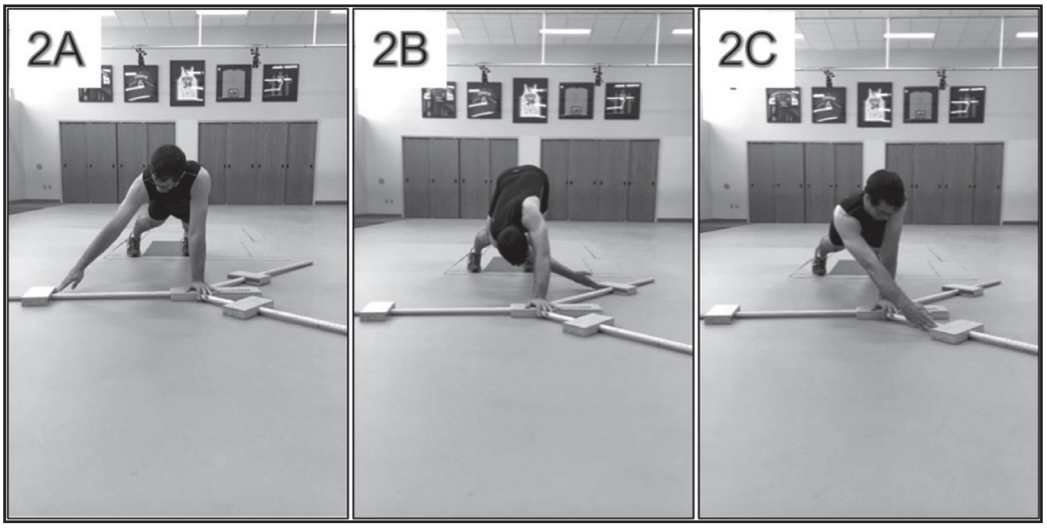

Figure 2. *YBT-UQ Reach Directions; (2A) the Medial reach, (2B) the Inferolateral reach, (2C) the Superolateral reach.*

three reaches were executed per trial. Two practice rounds and three data-collection trials were completed for both left and right limbs.[7] After each trial, the instructor recorded the data and returned each reach indicator to their original positions. During data recording, the athlete volitionally initiated a rest break between trials. The maximum score for each reach direction (M, IL and SL) during successful trials was normalized to the measured limb length and used to compute the composite scores for the throwing and non-throwing arms.

Data Analysis

Unilateral data (i.e., average unilateral trunk rotation, and YBT-UQ composite scores) were organized into throwing and non-throwing arms for analysis. Pearson's Correlation Coefficients ($p < 0.05$) were used to assess the relationships between the clinical measurements and the KJOC questionnaire. One correlation was used for each arm (throwing and non-throwing) to evaluate the relationship between unilateral trunk rotation and KJOC composite scores, as well as YBT-UQ composite scores and KJOC composite scores, resulting in a total of four analyses.

To address the second purpose of the study, one-way ANOVAs were used to assess differences in trunk rotation, YBT-UQ scores, and KJOC (composite and individual questions) and scores between the three groups ($p < 0.05$). Tukey's Post hoc was used for each of the significant contrasts to determine where differences were observed. Alpha was set at 0.05. Statistical analyses were completed using SPSS 21 (SPSS Inc., IBM, Chicago, Illinois).

RESULTS

No significant relationship was detected between measures of trunk rotation and the KJOC composite scores (throwing arm: $r = .239$, $p = 0.16$; non-throwing arm: $r = .291$, $p = 0.09$). However, a moderate, positive relationship was found between the YBT-UQ composite scores and the KJOC composite scores (throwing arm: $r = .413$, $p = 0.01$; non-throwing arm: $r = .380$, $p = 0.02$).

No significant differences were observed between throwing and non-throwing arms across groups in measures of trunk rotation ($p = 0.714$, $P = 0.38$) or upper quarter dynamic stability ($p = 0.73$, $p = 0.91$) (Table 2).

There was no significant difference in the KJOC composite score ($p = 0.08$) between the groups. However, the mean score for Item 1 (perceived limitations in warm-up) was different between all three groups, (Item 1 = IS: 6.7, INS: 9.7, UI: 9.1; $p = 0.02$) with the INS group reporting the greatest function. The mean scores on Item 5 (perceived strain on relationships with coaches) and Item 8 (perceived limitations in competition endurance) were also found to be significantly different between the IS and UI groups (Item 5 = IS: 7.8, UI: 9.5; $p = 0.02$ and Item 8 = IS: 6.4, UI: 8.8, $p = 0.04$) (Table 2).

Table 2. *Mean ± standard deviation and ANOVA results across groups.* ***Bolded*** *values indicate significant differences between groups ($p < 0.05$).*

Variable	Injured, surgical (IS), n=9	Injured, no surgery (INS), n=6	Uninjured (U)I, n=21	*p*-value
Trunk Rotation: Throwing Side (degrees)	70.1 ± 8.4	66.6 ± 7.6	69.9 ± 9.8	0.71
Trunk Rotation: Non-throwing Side (deg)	70.4 ± 8.6	75.5 ± 6.8	69.4 ± 10.3	0.38
YBT-UQ Composite: Throwing Side	91.0 ± 11.3	94.3 ± 7.1	94.1 ± 10.9	0.73
YBT-UQ Composite: Non-throwing Side	93.2 ± 9.1	94.9 ± 6.0	94.7 ± 9.4	0.91
KJOC Composite	74.2 ± 22.6	89.9 ± 9.0	86.8 ± 12.1	0.08
KJOC Item 1	6.7 ± 3.6	9.7 ± 0.5	9.1 ± 1.6	**<0.02***
KJOC Item 2	8.2 ± 2.3	8.0 ± 2.4	8.3 ± 2.1	0.94
KJOC Item 3	7.1 ± 2.7	8.6 ± 1.4	7.7 ± 1.7	0.38
KJOC Item 4	8.0 ± 2.5	9.3 ± 1.6	9.1 ± 1.2	0.25
KJOC Item 5	7.8 ± 2.8	10.0 ± 0.0	9.5 ± 1.1	**0.02†**
KJOC Item 6	7.3 ± 2.8	9.2 ± 1.4	8.5 ± 2.0	0.26
KJOC Item 7	7.4 ± 3.4	8.6 ± 2.9	8.8 ± 1.7	0.32
KJOC Item 8	6.4 ± 4.0	9.3 ± 1.3	8.8 ± 1.7	**0.04†**
KJOC Item 9	7.8 ± 2.4	9.0 ± 1.8	8.5 ± 1.9	0.54
KJOC Item 10	7.4 ± 3.3	8.7 ± 1.5	8.0 ± 2.5	0.48

Notes: *= all groups significantly different, †= differences between injured, surgical and uninjured groups YBT-UQ= Upper Quarter Y-Balance Test

DISCUSSION

Relationships between clinical measurements and patient reported outcome have potential to further the ability to clinically assess baseball pitchers. The two purposes of this study were: (1) to determine if there is a relationship between active trunk rotation, upper quarter dynamic stability, and KJOC questionnaire results, and (2) to determine if there are differences between pitchers with an injury history and those without in terms of their performance on active trunk rotation, upper quarter dynamic stability, and KJOC composite and individual scores. The first hypothesis was partially supported; the results of the current study suggest no association between trunk rotation and KJOC composite scores, but a moderate association exists between measures of upper quarter dynamic stability and KJOC composite scores in collegiate baseball pitchers. Regarding the second hypothesis, there were no differences between groups on KJOC composite scores, but on two of the 10 individual items (Item 5 and Item 8) pitchers with a previous upper extremity injury requiring surgical intervention exhibited lower scores when compared to uninjured players, and all three groups differed on one item (Item 1).

Relationship between trunk rotation, upper quarter dynamic stability, and KJOC scores

There was not a significant relationship between active trunk rotation range of motion and KJOC scores. Laudner et al.[25] assessed active trunk rotation range of motion in baseball players, and they observed decreased active trunk range of motion on both throwing and non-throwing sides (48.8 ± 6.4 deg. vs. 51.9 ± 6.6 deg, respectively) compared to the current study (69.6 deg. vs. 70.7 deg., respectively). Furthermore, other 3D biomechanical studies have measured upper trunk rotation during pitching, and demonstrate active trunk range of motion values very different from our own (52-55 degrees).[26,27] The current study analyzed active trunk range of motion as a controlled clinical measurement and no correlation was identified between active trunk rotation and the KJOC composite score. This may be due to fact that the KJOC assesses overall throwing function and does not have a specific rotation component to the patient reported outcome

measure. A meaningful relationship between the two may provide a clinical advantage, affecting functional outcomes in the rehabilitation setting.

Upper quarter dynamic stability, assessed using the YBT-UQ, provides a composite measure of mobility, strength and stability.[12,13] The results of the current study indicate that a moderate, positive relationship exists between YBT-UQ scores and the KJOC composite scores for both the throwing and non-throwing arms. There was no difference in throwing versus non-throwing YBT-UQ composite scores, which is consistent with the literature.[7] The overall YBT-UQ composite scores were also similar to previous studies.[7,17] As a result, upper quarter dynamic stability testing may be applied as a screen or measurement in return to sport criteria in conjunction with the KJOC. Understanding the relationship between upper quarter dynamic stability and an overhead athlete reported outcome measure may help practitioners better quantify athlete pitching injury susceptibility or acceptability to return to sport following injury.

Differnces in trunk rotation, upper quarter dynamic stability, and KJOC scores between groups

When pitchers were divided into groups based on their injury histories, no group differences were observed for active trunk rotation or YBT-UQ performance. The YBT-UQ requires trunk rotation, especially during the SL and IL reaches.[7] These findings suggest that all pitchers within this sample had the required active trunk rotation range of motion necessary to perform the YBT-UQ.

Several differences were identified between players with various injury histories on individual KJOC item scores. All three groups differed significantly on Item 1 (Question: How difficult is it for you to get loose or warm up prior to competition of practice? Scale: 0-Never feel loose during games or practice, 10-Normal warm-up time).[19] Specifically, IS had lower scores compared UI which, surprisingly, also scored lower than INS. Interestingly, pitchers from the INS group reported better ability to warm up compared to their uninjured counterparts. This could be due to INS pitchers having been fully evaluated and treated for all physical impairments. Furthermore, additional skills gained during rehabilitation in which strategic and comprehensive warm-up or stretches were taught could be a factor. This highlights the fact that there may be underlying physical impairments in fully participating and competing pitchers. These insidious impairments may be causing undue stress and strain during throwing and pitching, and thus affecting warm up, among other factors such as recovery between pitching sessions. Administering clinical physical exams to all pitchers, no matter their health status, could be conducive to identifying physical impairments that otherwise would not be recognized until after injury occurrence.

The IS group also had significantly lower scores on Item 5 (Question: How much have arm problems affected your relationship with your coaches, management, and agents? Scale: 0-left team, traded or waived, lost contract or scholarship, 10-not at all) and Item 8 (Question: What limitation do you have in endurance in competition due to your arm? Scale: 0-Significant limitation [became relief pitcher, switched to short races for example], 10-No endurance limitations in competition) compared to the UI group. Franz et al.[20] administered the KJOC during three different time points to major league and minor league baseball players over the course of one calendar year. In contrast to this study's results, they found players with a history of injury, both requiring surgery and not requiring surgery, had significantly lower composite KJOC scores that those without upper extremity injury histories. Furthermore, the mean composite KJOC score in professional baseball pitchers from their study (90.9) differed from the current study's mean composite KJOC score in college baseball pitchers (82.4). Kraeutler et al.[21] identified a mean total KJOC score of 94.8 in 44 professional baseball pitchers, and found that in AAA baseball players scored higher than AA players. Like the current study, Paci et al.[23] identified a lower mean total KJOC score (86.9) in college pitchers than that reported by minor league and professional pitchers in the studies by Franz and Kraeutler.[20,21] Collectively, these results suggest that higher-level pitchers have better perceptions of their throwing arms than pitchers at lower levels, according to patient reported outcomes.

The KJOC Composite score between the three groups were not different. This is consistent with Alberta et al.[19] in which fully participating and healthy overhead

athletes had similar KJOC scores, no matter previous injury history. While there were differences between different individual questions, only the overall composite score has been validated.[18] The KJOC composite scores may not have the clinical sensitivity to fully detect small variations and decrements in fully participating college baseball pitchers.

There is a need for future research following these findings. There is little understanding between the relationship of active and passive trunk rotation, YBT-UQ, and injuries. Prospective investigations are needed to comprehend if there is a relationship between these clinical assessments and injuries. As previously stated, the use of individual KJOC questions has not been validated. In light of this study's findings, further research is necessary to understand if each individual KJOC question can be used independently as a patient reported outcome measure, and has the clinical utility to identify pitchers that are more at risk for injury. Lastly, more analysis is required to understand if the composite KJOC score has enough clinical sensitivity to identify pitchers with past injury histories that may still have physical impairments affecting their injury risk.

Limitations

As with all studies, there were limitations to this study. A cross-sectional cohort design was utilized for this exploratory analysis. This methodological approach permitted data to be collected at one time point, and pre-season testing was intentionally chosen in an effort to avoid potential confounding effects of overuse or fatigue related injuries. It is possible that the correlations between trunk rotation ROM and the KJOC, and the upper quarter dynamic stability and the KJOC may change throughout a season. As a result, a longitudinal study to understand how these relationships change throughout a competitive season is warranted. This investigation did not include previous training history. Each college program has different practice and training habits that may have affected the data. Understanding this potential selection bias, a variety of college baseball programs were incorporated into the data collection in an effort to make the results more generally applicable to this population. Furthermore, while this study recruited a sufficient number of subjects to potentially discern a difference between groups, overall this study had a low number of subjects. Further studies are needed with higher power to investigate relationships between the KJOC, trunk rotation, and upper quarter dynamic stability. Lastly, this investigation utilized a stationary, seated method to analyze trunk rotation,[24] while past studies[26,27] have measured range of motion using 3D biomechanical analysis during pitching. This relationship between a clinical test showing active range of motion and biomechanical measurements of utilized range of motion during pitching should be further evaluated. Research aimed at identifying methods of assessing trunk rotation in pitchers, which do not require expensive motion capture technology, is desirable.

CONCLUSIONS

The results of the current study demonstrated no significant relationship between KJOC scores and trunk rotation among collegiate baseball pitchers. However, there was a moderate association between measures of upper quarter dynamic stability and the KJOC composite score in Division I collegiate pitchers. This study found that compared to college baseball pitchers with a surgical history, pitchers without a surgical history had significantly higher KJOC scores for warm up time, competitive endurance, and impact on team relationships. Surprisingly, pitchers with injuries that did not require surgical intervention reported greater perceived function than their uninjured counterparts. Players with a surgical history reported decreased relationship with coaches and throwing endurance when compared to those without an injury history. Future studies should continue to investigate the important relationship between functional and patient reported outcome measures to inform clinical practice regarding the examination of the throwing shoulder.

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